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The Editor's Page

A Conference on Cotton and Rayon Warp Sizing

SO successful and resultful was the conference on fabric wear resistance and wear testing, held by U. S. Institute's Research Council, March 24 (see summary report, p. 348) that the Council decided at its meeting April 11 to utilize the conference method of analyzing and developing a research program for another important and unsolved textile problem: The Sizing of Cotton and Rayon Warps.

This conference, which will be open to all interested in the subject, will be held at the Hotel Commodore, New York City, Friday, May 11th, starting at 10 A.M. Luncheon will be served at $1.50 a plate, and there will be an afternoon session. The program will be completed before this announcement is published and copies may be obtained by addressing the Secretary of U. S. Institute.

The Research Council recognizes that sizing as practiced in the finishing of textiles involves more fundamental problems for scientific research than does warp sizing, yet it believes that many of them will emerge in the conference on the latter subject, and that this initial conference will be a logical introduction to a discussion of sizing in its broadest aspects.

Quarterly Meeting of Directors

The third quarterly meeting of the Board of Directors and of the Executive Committee of U. S. Institute will be held at the Hotel Commodore, New York City, at 12:30 P.M., Friday, May 11, starting with luncheon.

A Correction

Through a misunderstanding it was stated on p. 301 of the April number that Mr. Sisson's report, ending on that page, was presented by him "before the Division of Cellulose Chemistry at the Chicago meeting of the American Chemical Society, Sept. 10–15, 1933." This note has reference to another report by Mr. Sisson yet to be published in TEXTILE RESEARCH.

The Detection in Dyed Textiles of Small Color Differences

By ROBERT D. NUTTING*

THE art of dyeing textiles is one of extreme antiquity and its development closely parallels that of civilization. If one inquires into the technique used by the dyer in making a color match, it is found that the methods are largely intuitive and that the dyer is guided chiefly by his many years of experience. During this time he has been able to set up an arbitrary scale of color values in terms of the concentrations of the dyestuffs with which he is familiar. The development of new color measuring instruments within the last few years has provided a tool which should prove very effective in the hands of a trained dyer and should materially assist him in meeting the ever-increasing pressure of competition.

The Eye is not an Analytical Instrument

There is little question that the trained human eye is a very sensitive mechanism for the detection of small color differences. Thus, a dyer confronted with two yellow swatches may describe one of them in a qualitative way as being redder than the other, even when the difference is very slight. He may even indicate the degree of the difference in a quantitative way by stating the difference in the amounts of the dyestuffs used. It can be seen that with this system each dyestuff or combination of dyestuffs must be considered as a special case, and the scale of color values established for one such case can not possibly be extrapolated to include mixtures of different dyestuffs. In other words, a dyer is unable to predict accurately the color that will be produced by mixing two dyestuffs if he has not already made a scale of mixture values for these materials.

The reason why so many arbitrary scales of color values must

* Dr. Nutting is a Senior Fellow of The Textile Foundation working under the direction of Prof. Arthur C. Hardy at the Massachusetts Institute of Technology, Cambridge, Mass., on The Spectrophotometric Analysis of Dyed Materials.

be established is that each scale is made in terms of the chemical composition of the dyebath, rather than in the purely physical measurements of the color itself. The eye is not an analytical instrument and is therefore unable to present its observations in any fundamental units. The process of color perception is a process of integration and, as is generally appreciated, the color of an object is determined, not only by the characteristics of that object, but also by the quality and quantity of the light with which it is illuminated. If this illumination is altered the object may appear to the eye to have a different color, whereas, in truth, its fundamental characteristics have in no way been changed. It should be apparent then that some analytical method must be employed that will give an unqualified representation of the characteristics of the object alone. The instrument for so measuring the reflectance of materials is known as a spectrophotometer, or color analyzer, and is designed to measure the amount of light reflected from the colored object at each wavelength of the visible spectrum.

The spectrophotometric method not only provides a wealth of information that can be secured in no other way, but it is so fundamental that the results obtained with it can be readily translated into the more familiar terms of dominant wavelength, purity, and brightness, or for that matter into any other terms that may be found convenient. One is naturally prompted to ask why the spectrophotometer has not found a more general use in that most likely field, the dyeing of textiles. The answer to this is probably to be found in the fact that in the past all such measurements had to be made with a visual-spectrophotometer. To obtain a complete spectrophotometric curve in this manner requires considerable time and patience. Furthermore, the data may be of questionable accuracy, especially in the blue and violet portions of the spectrum because of the difficulty in making settings in this region. The development of a rapid recording photoelectric-spectrophotometer, at the Massachusetts Institute of Technology by Prof. Arthur C. Hardy, has provided a means of obtaining the necessary spectrophotometric data with adequate precision and in a matter of only a few minutes. It was in the belief that sufficient data to throw more light on the important problem of textile dyeing might be obtained with this

color analyzer that this program of research,[1] of which this paper is a part, is being sponsored by the Textile Foundation.

The Draves Conclusions

In spite of the general recognition of the fundamental validity of the spectrophotometric method of color specification, C. Z. Draves [2] has concluded that the human eye is a better judge of small color differences than a visual-spectrophotometer. Since this entire program is based on the use of the spectrophotometric method, it seemed necessary to establish at the outset that his conclusions do not apply to photoelectric-spectrophotometry with an instrument of suitable design. Draves' conclusions were based on experiments which consisted in dyeing swatches of wool with a yellow dye, and with a mixture of yellow and red dyes. The percentage of yellow dyestuff was maintained constant in every case while the amount of red was varied. Draves found that he could perceive color differences between the various swatches with his eye that did not show up in his spectrophotometric analysis. Since he confined his determinations of reflection to only one wavelength, it was felt that his conclusions needed further investigation.

The M. I. T. Recording Spectrophotometer

The dyeings made in the experiments reported herein followed as closely as possible those described by Draves, and the spectrophotometric curves were made with the recording spectrophotometer previously mentioned. This will be described in more detail by Hardy, and only a brief summary of its operation will be given here. Light from a tungsten lamp is dispersed into a spectrum by means of a double monochromator, and a narrow spectral band is allowed to enter the photometering system. The latter consists of a set of three polarizing prisms, an integrating sphere and a photoelectric cell. One of the three prisms (a Wollaston prism) splits the monochromatic beam into two beams. These two beams are made to fall alternately upon the sample and the standard white by means of a Rochon prism rotating at constant speed of 30 revolutions per second behind the Wollaston prism. The intensities of the two flickering beams are varied by means of another Rochon prism, free to turn about its axis, in front of the Wollaston prism. Light is reflected by the sample

or the standard to the whitened walls of the integrating sphere and then to the photoelectric cell, which is shielded from polarization effects by a ground glass plate. A difference between the reflectance of the sample and that of the standard causes a pulsating current in the photoelectric cell, and this is amplified sufficiently to drive a small motor. The motor rotates the Rochon prism, located in front of the Wollaston, about its axis until the two flickering beams reflected from the sample and the standard reach the cell with equal intensities. The magnitude of this rotation is a measure of the reflectance of the sample and may be read directly, if desired, from a divided circle. However, the rotation of this prism is also translated into a linear motion, and is automatically recorded by means of a pen on a sheet of coordinate paper. The wavelength of the monochromatic light entering the photometer is altered at a constant rate, and is recorded by a motion of the coordinate paper perpendicular to that of the pen. This color analyzer is a null instrument and the reflectance measurements are independent of the intensity and quality of the light source, the sensitivity of the photoelectric cell, or the gain in the amplifying circuit. In the measurements presented here the standard was always a block of magnesium carbonate freshly smoked with magnesium oxide and tested for its uniformity.

The Draves Dyeings

The dyeings made by Draves contained the amounts of yellow (duPont Tartrazine 0) and red (Crocein Scarlet Conc.) dyestuffs shown in the following table:

TABLE 1

	% of Dyestuff by Weight of Cloth	
Sample No.	DuPont Tartrazine 0	DuPont Crocein Scarlet Conc.
1	1.0%	zero
2	1.0	0.0001%
3	1.0	0.0002
4	1.0	0.0050
5	1.0	0.0010
6	1.0	0.0020
7	1.0	0.0050
8	1.0	0.0100
9	1.0	0.0200
10	1.0	0.5000

Crocein Scarlet has an absorption maximum at 510 millimicrons. Draves naturally expected that the greatest effect would be produced where the absorption of this dye is a maximum, and he therefore confined his spectrophotometric observations to this wavelength. He stated that the presence of "1/5000% of the

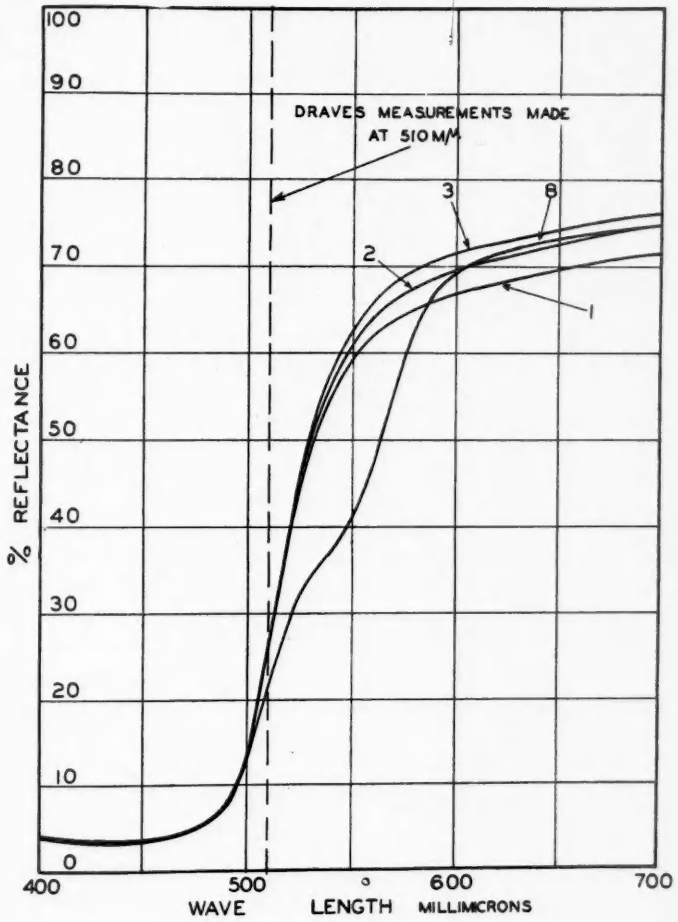

FIG. 1

red could be quite definitely distinguished visually because it made the yellow dyeing slightly redder in hue, whereas 1/10,000% of red was not always distinguishable." In other words, he could always distinguish between samples 1 and 3 but not between 1 and 2. However, he could observe no differences at all between these dyeings from his spectrophotometric examinations made at 510 millimicrons.

Referring to Fig. 1, the curves of which are spectrophotometric analyses of swatches dyed in the laboratory of Dr. R. E. Rose of the E. I. du Pont de Nemours Co., Inc., and reproduced here with his kind permission, it is seen that the various dyeings (which are numbered in the order given in Table 1) are clearly differentiated. These curves are in close agreement with those consistently obtained in this laboratory on dyeings made according to Draves' technique. It should be noted that the difference in reflectance between samples 1 and 2 is approximately 3.5% at the red end of the spectrum. This difference is evidently significant, since the color analyzer can be depended upon to reproduce the curves to within a fraction of the width of the penline. Hence, we may conclude that there is no difficulty in determining by the spectrophotometric method a color difference that is quite imperceptible to the unaided eye.

It is interesting to note that Draves described the difference between samples 1 and 3 as a difference in hue. This judgment was evidently based upon his knowledge of the effect produced by larger quantities of the red dye. Referring to curve 8 in Fig. 1, it will be seen that 0.01% of the red dye does definitely shift the hue toward the red end of the spectrum. The curves in Fig. 1 have been converted, according to the Standard Observer and Coordinate System for Colorimetry, outlined by Judd,[3] into dominant wavelength, colorimetric purity, and luminosity (brightness) with the following results:

TABLE 2

Sample	Dominant Wavelength mμ	Colorimetric Purity %	Luminosity %
1	577	92	54.2
2	577	92	55.9
3	577	92	57.3
8	582	90	47.1

It will be seen that the principal effect of adding a small amount of Crocein Scarlet Conc. is to increase the brightness of the swatch and that larger quantities are required to produce a shift in the hue (dominant wavelength). Hence, although Draves was able to distinguish between samples 1 and 3 by merely look-

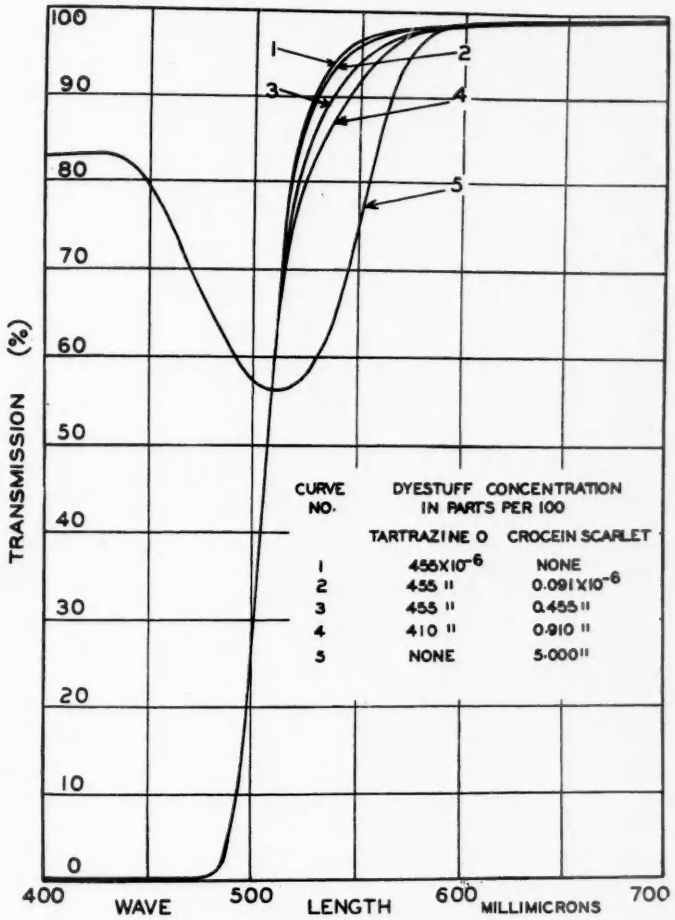

FIG. 2

ing at them, he was unable to state correctly the manner in which they differed.

The anomalous effect produced by small amounts of the red dye (curves 2 and 3) would undoubtedly have been detected by Draves, even with his visual-spectrophotometer, had he continued his observations throughout the spectrum. This effect is a definite increase in reflectance at the red end of the spectrum when small amounts of Crocein Scarlet Conc. are added to Tartrazine 0 on wool. This is entirely contrary to the effect that would be expected and so far as we know has not been previously recorded. That these curves do represent an anomalous behavior of these dyestuffs will be apparent from Fig. 2. Here it is seen that successive small additions of the red dye to a solution of the yellow dye lower the transmission in the manner that would be anticipated from Beer's law. Since these same additions actually raised the reflectance of the dyed wool, it must be concluded that this peculiar behavior is undoubtedly connected with the manner in which these dyes are taken up by the cloth. An explanation of this inconsistency will not be attempted at this time, since the purpose of this paper is merely to show the applicability of the spectrophotometric method to the detection of small color differences. It is hoped that the results given here will definitely serve to remove any prejudice that may have been formed against the precision of the spectrophotometric method and will encourage other investigators to apply it to their particular problems of color measurement.

References

1. The Spectrophotometric Analysis of Dyed Materials. *Tex. Rsch.*, Oct., 1933, P. 479.

2. *Am. Dye. Rptr.*, 1933, V. 20, P. 389.

3. *Ibid.*, 1933, V. 23, P. 359.

Elastic and Plastic Properties of Textile Fibres

Part III.—Swelling of Cotton and Cellulose Acetate When Exposed to Air at Various Relative Humidities

By RAYMOND L. STEINBERGER *

Abstract

A method is described whereby the swelling of single fibres in air of varying relative humidity (R. H.) may be watched under the microscope. Results for changes in exterior dimensions and twist of a cotton fibre, also for changes in section area in both cotton and Celanese, with changes in R. H. are given. The rate of contraction of section area in Celanese when the dry fibre is exposed to air at 100% R. H. and the rate of swelling of section when the wet fibre is exposed to dry air are given. A qualitative explanation of results is offered.

Introduction

DURING the stress-strain study [1, 2] it was of course realized that sorbed moisture within the fibre has a great effect on the mechanical properties. The stress-strain relation was therefore studied under known conditions of humidity. Moisture sorption enters the determination of the tensile properties of textile fibres in two general ways: (*a*) through change in section area which enters into the unit stress computation and (*b*) through the intrinsic effect on cohesive forces. It seemed advisable therefore to go into the subject of swelling phenomena a little deeper. A technique for studying the change in section area in any fibre has been developed. The result of the study on section area change with humidity has led to the adoption of the standard procedure of basing unit stress computation on

* Dr. Steinberger is a Senior Fellow of the Textile Foundation working under the direction of Prof. P. W. Bridgman, Harvard University, Cambridge, Mass.

the equilibrium section approached by the fibre in the dry condition. The other effect, the influence of moisture on cohesive forces, is a much more complex problem which for satisfactory solution will lead rather deeply into the fundamental study of swelling and the physics of gels.

Experimental: Humidity Control

The humidifier described previously [1] has been elaborated so that the R. H. of the air about the specimen can be varied in nominal steps of 10% from dryness to saturation. The treated air can be led through the tension apparatus, or can be led over the specimen mounted on the stage of a microscope so that changes in size can be watched. The humidity control consists of a battery of large test tubes (1″ × 8″) of 75 c.c. capacity partly filled (50 c.c.) with H_2SO_4 solution through which the air can be led (Fig. 1). The tubes are arranged in pairs. The two tubes of each pair contain solutions of the same composition. The initial level is marked on the tube. The air from the laboratory supply was initially led through a $CaCl_2$ drying tube, so that if there is any change in acid concentration it will consist in a decrease of water content and a fall in solution level. To bring the solution back to its calibration value it is only necessary to add sufficient water. If the air were not initially dried the acid concentration would decrease. To bring it back to its calibration value would

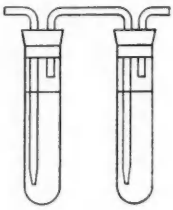

FIG. 1.

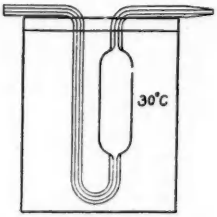

FIG. 2.

mean the addition of acid and troublesome recalibration. Distilled water was used, which had been boiled to remove dissolved air so that density determinations would be reliable. The first tube in each pair practically completes the vapor pressure adjustment, so that the second tube remains constant in concentration through long usage. In order to obtain as steady a flow of air as possible, it is necessary to draw down the tip of the tubes, through which the air enters, to as fine a point as possible, permitting the formation of small bubbles. The limit of orifice size is determined by the air pressure available (which is usually ample) and the ability of the rubber stopper and tubing connections to withstand pressure. Stoppers and tubes, if well set in a dry condition, will stand 5 or 6 pounds per square inch before blowing out. The pressure required to blow through a small opening immersed under a liquid varies inversely as the diameter.

Eleven 100 c.c. solutions were made up roughly by hydrometer for the proper densities to give 0 to 100% R. H. in nominal 10% steps. The density-vapor pressure relation was plotted from data given in the International Critical Tables for the three temperatures 0°, 25°, 50° C. covering the probable range of working temperatures. Since the density can be measured accurately, and the pressure-density relation for H_2SO_4 solutions is known with precision, the indirect method of calibration is more accurate than the direct determination of the R. H. of the treated air. A gravimetric determination of vapor pressure was, however, made at first [3] for each unit. The results did not agree accurately with a later density calibration. The results of the latter method were retained as more reliable and used throughout the research. The apparatus was constructed to permit only a slow flow of air (about 6 liters per hour). In order to get a convenient increase in weight of drying tube used in the gravimetric method the flow had to be continued for long times, especially in testing the more concentrated solutions. The barometer height and room temperature which enter into the computation had ample time to change by measurable amounts.

Density determination was made at 30° C., using the type of pycnometer illustrated in Fig. 2. This is a particularly convenient form to use. It is much more readily cleaned and filled than the usual bottle type. 30° C. is sufficiently above room temperature to eliminate the use of any cooling arrangement in the adjustment of temperatures. The method is, however, unnecessarily accurate and time consuming and will, therefore, in future work, be replaced by the use of a Westphal balance. The density determinations resulted in the humidifier calibration given in Table I.

TABLE I

Humidifier Calibration

Nominal R. H.	R. H. at 21.7° C.
0	< 0.5 %
10	14.30
20	24.06
30	34.88
40	45.74
50	55.69
60	65.22
70	76.45
80	82.80
90	90.36
100	——

A general view of the humidifier arranged for use with the microscope is shown in Fig. 3. The brass cell, sketched in Fig. 4, can be seen attached to the microscope objective. It confines the humidified air to a space of very small volume (about 2 c.c.) surrounding the objective J, and the paraffine disc P and fibre specimen f. The fit F of the ring is close enough to permit a negligible escape of air and prevent cocking of the cell, but is still sufficiently loose to permit the objective tube to slide through it, facili-

tating focus adjustment. The beveled edge E fits the flat surface of the slide S, preventing escape of air. The heavy collar R is useful in giving mass to the whole device so that contact on the slide is positive. When the microscope is racked up the knurled rim K of the objective tube keeps the cell from falling off. The front lens of the objective must be removed when the cell is put on. The treated air is led in through the orifice O_1 and out through O_2. A positive flow of air over the specimen is assured.

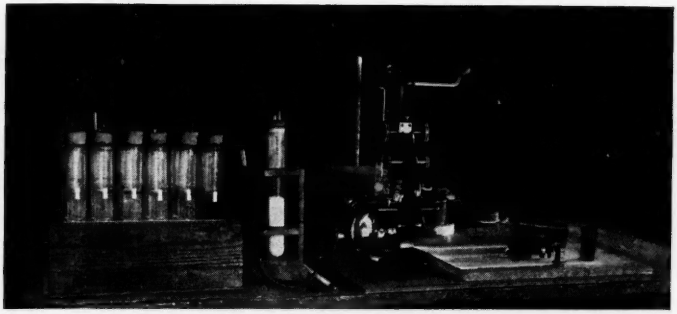

FIG. 3.

Results: Swelling of Cotton in Humidified Air; Diameter Measurements on Cotton

A length of Egyptian cotton fibre was cemented diametrically across a small brass ring, 1 cm. by 2 mm² section, and was then placed on the stage of the microscope equipped with the humidifying cell. In air at low humidities the fibre is found in the form of a flattened and twisted hollow tube. As the R. H. increases, the fibre tends to untwist locally and to swell, changing its outline of section, approaching more and more a circular form. Many twists exist in a length of one centimeter, but in this length the total twist is approximately zero, for there are on the average just as many left hand twists as right per unit length. One well defined 180° twist was decided upon for examination. Drawings were made with transmitted light and a camera lucida attachment. There are three (listed below) rather serious sources of error in the method, but some results have been obtained which have sufficient interest to warrant their description: (1) Light transmitted through a translucent substance such as cotton renders the outline somewhat ambiguous. (2) Even a carefully made drawing does not reproduce the object with precision. (3) Measurements from the final drawing, which is a lens-shaped figure, of maximum width 1.6 cm. by 7 cm. long, also can not be made with much accuracy. The width of the figure perpendicular to its long axis was measured at 17 equally spaced intervals. Measurements at the center give the maximum fibre diameter, but the minimum figure width does not necessarily measure the minimum fibre diameter for the figure of cross-section is not convex (especially at high degrees of dryness) around its entire perimeter. However, the aver-

age of the 17 readings is a number the per cent variation of which should approximate the per cent variation of any given diameter of section. For high R. H. the 17 readings were more widely spaced because the fibre untwists. The result is equivalent to a measurement of diameter along directions always having the same angular distribution about the axis of the fibre.

Before the actual measurements were made, saturated air was led over the specimen throughout the preceding night to be sure of at least a close approach to equilibrium size. The variation of twist length and average diameter are shown in Figs. 5 and 6 as the R. H. falls from 100% to zero. As R. H. falls, the fibre twists steadily into a tighter spiral. The lens-

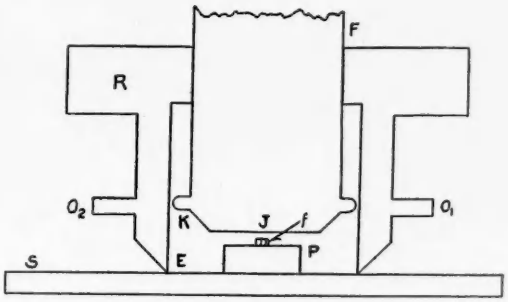

FIG. 4.

shaped sketch contracts in length. The scattering of the points is not too great to enable one to draw an average curve with considerable assurance. In Fig. 6 the diameter changes are plotted in per cent of the dry value. The maximum variation amounts to about 22% increase between dryness and saturation. If the figure of section were always geometrically similar to its dry form the section area change would be about 44%, since $2\,\Delta\,d/d = \Delta\,a/a$ where d and a are diameter and area, while Δ d and Δ a are changes. Fifteen minutes elapsed between changes in humidity. It was not yet known whether this duration was long enough for the attainment of equilibrium size. As a qualitative check, direct measurements on the maximum and minimum diameters were made with a micrometer ocular. It must be remembered that the minimum as measured here is not the true fibre minimum diameter. The absolute values of the recorded figures are therefore meaningless. Relative values, however, have some significance. After remaining in the dry air stream for 20 hours, which should be sufficient for the attainment of equilibrium size, the humidity was increased in steps of 10% up to saturation with the results illustrated in Figs. 7 and 8. It should be noted in Fig. 8, that with rising R. H. up to about 20% there is a fall rather than an increase in diameter. Note also that the maximum diameter at first increases more rapidly and approaches a constant value, while the minimum is the reverse. This means that the section figure tends to take a circular form and may possibly attain it when soaked for a long time in water. After 20% R. H. the per cent diameter

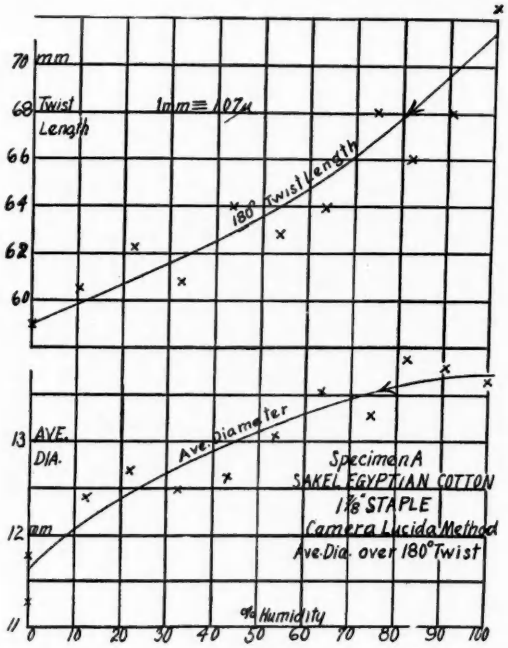

FIG. 5.

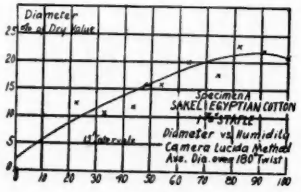

FIG. 6.

change is proportional to the R. H. (Fig. 8). Comparing Fig. 6 with Fig. 8 it is obvious that if the two curves were plotted on the same paper there would be a certain amount of hysteresis of size change with R. H. This suggests a time effect and indicates that the points of Figs. 6 and 8 do not indicate equilibrium conditions. It may be that, if one waited long enough, there would be only one instead of two values for a given diameter, regardless of whether the humidity is rising or falling. The signifi-

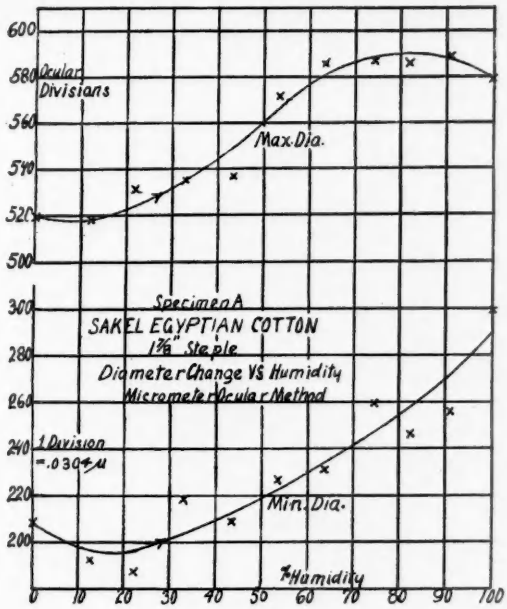

FIG. 7.

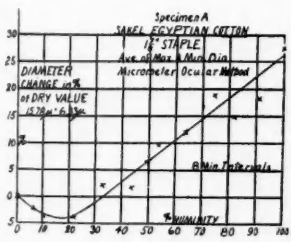
Specimen A
SAKEL EGYPTIAN COTTON
1 7/8" STAPLE
Ave. of Max. & Min. Dia.
Micrometer Ocular Method
DIAMETER CHANGE in % of DRY VALUE
% HUMIDITY
0 10 20 30 40 50 60 70 80 90 100

FIG. 8.

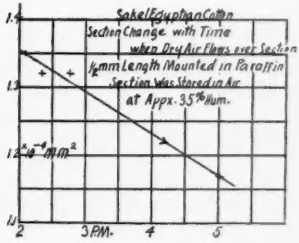
Sakel Egyptian Cotton
Section Change with Time
when Dry Air Flows over Section
½mm Length Mounted in Paraffin
Section was Stored in Air
at Appx. 35% Hum.
2 3 P.M. 4 5

FIG. 9.

cance of the above remarks will be more fully appreciated after the results for cellulose acetate are presented.

Change of Section Area of Cotton in a Paraffine Mount

The mounting of the fibres in the sectioning process described previously[2] differs from the paraffine mounting method of the botanist, who

works with recently killed tissues, mainly in the absence of the paraffine infiltration technique. Textile fibres are dead, relatively dry, and contain no fluids which must be replaced by paraffine. It had been observed that even in the well-mounted fibres there was an observable fissure between the fibre and the paraffine. The possibility at once appeared that the atmosphere may be able to penetrate the mounted fibre in spite of its enveloping paraffine. Such actually seems to be the case as indicated by a rough preliminary experiment. The cotton mounts from which the section areas for Tensile Test No. 2 and No. 3, Table I, given in [1], were obtained were placed on the microscope with one paraffine disc under the humidifying attachment. The room humidity was 35%. The section was sketched at intervals after the dry air was turned on with the results shown in Fig. 9. The area falls from 1.35×10^{-4} mm² to 1.17×10^{-4} mm² in a period of 3 hours, or about 13%. At a later date the same fibre section was measured at the room R. H. of 52%. Saturated air was then turned on. Fig. 10 indicates the course of the area increase with time. At the end of one hour and twenty minutes dry air was turned on. The area decreased again. The points scatter seriously because of the experimental errors, the sources of which are enumerated below.

Cellulose Acetate (Celanese): Swelling of Section Area

It is difficult to make accurate measurements on cotton: (1) It has a very small diameter; (2) has a central canal hard to sketch accurately; (3) is tough and difficult to cut in the sectioning process; (4) is a natural fibre with secondary structures which may complicate swelling phenomena. Celanese fibre does not possess the above disadvantages, and was therefore selected for further development of technique, which will then be applied again, when perfected, to the investigation of cotton. One well-defined section of the group on which the area for the curve (Ref. [1], Fig. 10) was meas-

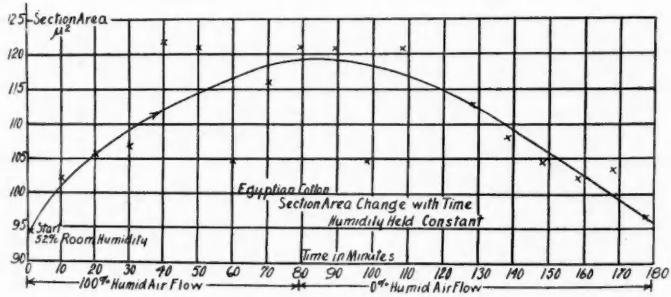

FIG. 10.

ured, was prepared for examination. The contact between Celanese and paraffine was good. It was feared that water vapor would not penetrate the fibre through the sides easily enough. The system of etching described

previously [2] was therefore developed, whereby the surface of the paraffine disc could be slowly etched away, allowing the fibre to stand out above it so that the humidified air could readily enter the fibre. The relations between section area, R. H., and time of exposure are illustrated in Figs. 11 to 16 for the single specimen of Celanese whose mounting method has been described.

Figs. 11 and 12 belong to the same run and should be considered together. The specimen stood overnight in the air of the room at R. H. 20%.

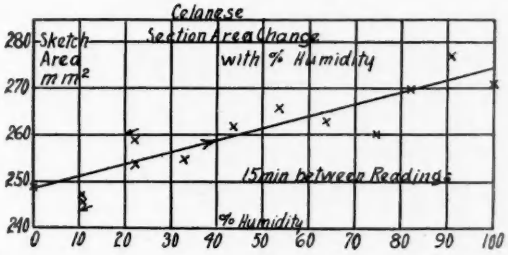

FIG. 11.

At 15-minute intervals the area was determined as R. H., was changed in nominal steps of 10% from 20% to zero and then back to 100%. The area changes are illustrated in Fig. 11. After the attainment of 100% R. H. the saturated air flow was continued. The area continued to increase with time as shown in Fig. 12 and attained its maximum value some time during the night. The maximum sketch area was 300 mm²; a figure which was obtained again and again. It is truly reproducible and

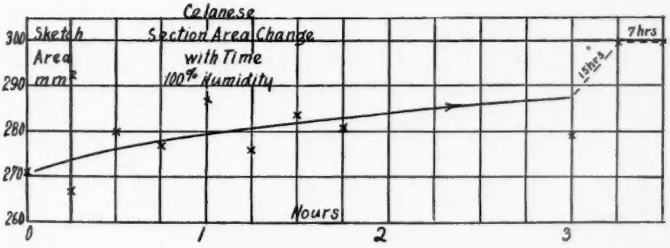

FIG. 12.

the fibre possesses the property of limited swelling. The attainment of the maximum size takes place very slowly. The opposite condition exists when dry air is led over a wet specimen. The surprisingly rapid change will be appreciated when Figs. 13 and 14 are examined.

After the last point on Fig. 12 was obtained the saturated air flow was continued for 45 hours, with no change in sketch area. The air flow was then suddenly shifted from 100% R. H. to zero. The fall of area with time is shown in Fig. 13. The entire decrease takes place in one hour. In order to decrease somewhat the probable error each point represents the average of six instead of one sketch.

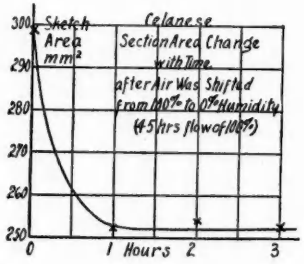

FIG. 13.

From the dry condition at the end of the curve (Fig. 13) where the area was 253 mm², the R. H. was again suddenly raised from 0 to 100% after the specimen had remained in the dry air flow for 18 hours. The results are given in Fig. 14. Note that the area maximum is approached very slowly. The points scatter considerably more than they do in Fig.

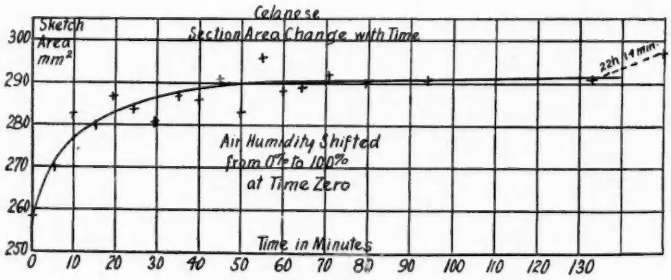

FIG. 14.

13 because each represents but one sketch measurement. An attempt was made to determine more points on the curve (Fig. 13) in the first hour after turning on the dry air. The rate of shrink was found to be much more rapid than Fig. 13 indicates. This is clearly shown in Fig. 15. As in the previous cases the maximum sketch area 300 mm² was obtained by letting the saturated air flow for about 18 hours before the dry air was turned on. Five sketches were drawn and measured for each point marked by a cross. This process was too slow to reveal the rapid change in the

neighborhood of one-half hour, so that the single areas marked by circles had to be plotted. Approximately the whole area decrease took place in the short interval of two minutes. The slow beginning of the curve is undoubtedly due to the slow removal of condensed moisture in the piping system and on the specimen itself. After long flow-times with saturated air, minute drops of water could be seen on the specimen and in the glass connecting tubes. The black circles represent the data from Fig. 13. The agreement is good. The curve exhibits a minimum area near t = one hour, and a secondary maximum near two and one-half hours. The cause of

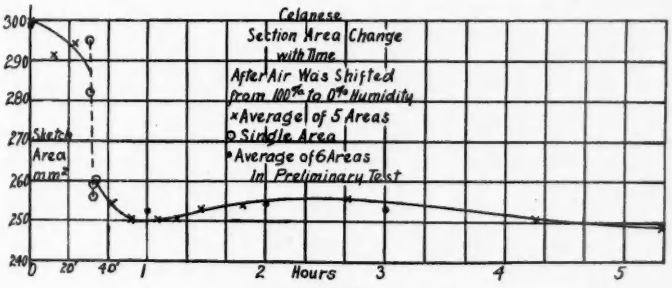

FIG. 15.

this is obscure but an explanation will be ventured in the discussion to follow. The individual areas are plotted in Fig. 16 on a slightly larger time-scale in order to show how the points scatter because of inaccuracies in drawing and measuring the sketches.

Curves 14 and 15 have a definite bearing on any attempt to determine the equilibrium relation between section area and R. H. With R. H. in-

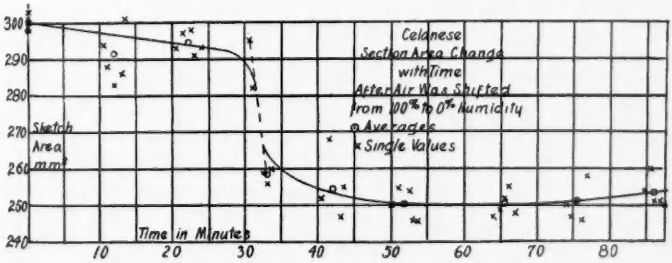

FIG. 16.

creasing from zero, equilibrium is attained slowly; while decreasing from 100% equilibrium is attained very rapidly. Two equilibrium curves are given in Figs. 17 and 18 for increasing and decreasing humidity respectively. In the first, equilibrium is probably only partially attained. Note

that the slope of Fig. 17 is less than Fig. 18. To wait for complete equilibrium with rising humidity would, in the light of Fig. 17, be prohibitively time consuming. The whole curve of Fig. 17 represents the lapse of 100 minutes, a time long enough for about 80% of the total increase in area as judged from curve 14. The rapid fall of curve 15 indicates that with R. H. falling from 100%, rapid equilibrium of size may be obtained. This is an important point, for it is reasonable to expect that other properties which depend on water sorption from the atmosphere would also quickly attain equilibrium under like conditions. In future studies on the stress-strain relation this will be kept in mind.

The slope of the straight portion of Fig. 18 gives an area decrease of 0.15% (computed on the basis of the dry area) for each per cent drop in R. H. There is a large initial drop near R. H. = 100%, amounting to 8.6% of the dry area. The significance of this will be discussed later. Each point in Fig. 18 represents the average of five sketch areas determined by a carefully calibrated planimeter, set for the measurement of small areas. With this instrument the sketch perimeter can be traced quickly and as often as desired without destroying the drawing. In the present case each of the five sketches were traced five times. The averages of the 25 determinations give the points of Fig. 18. The most accurate method of sketching is to use a sharp, hard pencil and make a series of dots around the image perimeter, rather than to draw a continuous line which has a tendency to insinuate itself away from the edge of the image. The times

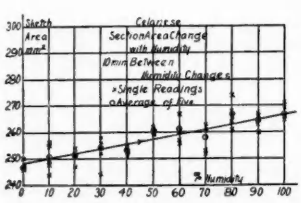

FIG. 17.

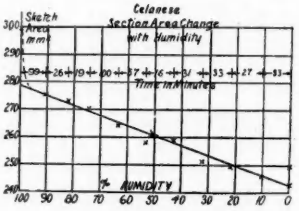

FIG. 18.

between readings are listed in Fig. 18, and show that there is no systematic variation which can be ascribed to incomplete attainment of equilibrium. The scattering of the points may be due to errors in R. H. values. However, the deviations are not large enough to warrant a recalibration of the humidifier. This will be done at a later date when other fibres are examined. Fig. 18 gives what is believed to be the true equilibrium size as a function of R. H. The curve begins with a wet fibre and ends at zero R. H. From Fig. 15 it is evident that the time between observations in Fig. 18 are ample for the attainment of equilibrium size while with rising R. H. (Fig. 17) this is not the case.

Discussion of the Results of Swelling Measurements

The immediate object of the swelling investigations was the determination of the true cross-section of a given fibre in any R. H. The area

variation has been determined in the case of cellulose acetate from an examination of a cut end. The objection may naturally be raised that there is no positive assurance that the swelling of a cut end will be exactly equal to the swelling of cross-section in the body of the fibre. However, it is reasonable to assume that the difference will not be great. In any case no serious errors will enter into the s.s. determination, for section swelling enters only as a correction. The excuse for presenting the information here in some detail is that the facts have considerable interest on their own merits, and may be useful when the intrinsic effect of moisture on tensile properties is studied in detail.

Textile fibres are true colloidal gels under ordinary conditions of temperature and humidity. A comprehensive study of their swelling properties would lead one far astray into the field of colloidal chemistry. Only a few remarks culled from the voluminous literature on the subject, and which bear directly on the questions at hand, may properly be made here.

Colloidal gels exhibit either limited or unlimited swelling. Textile fibres belong to the former class when swollen with water or water vapor. The swelling proceeds to a maximum value. The terms limited and unlimited swelling are relative and apply only to the particular system of gel and dispersing medium. Cotton exhibits limited swelling in water, and unlimited swelling in cuprammonium solution where the ultimate end-product, with sufficient dilution, is a single chain of glucose residues. The fibre loses its identity entirely.[4] Celanese (cellulose acetate) clearly exhibits limited swelling in water. The maximum area of section was repeatedly obtained (Figs. 12, 13, 14, 15, 18). The swelling limit in saturated air (*i.e.*, a mixture of air and water vapor) is considerably less than in water, amounting to a difference of about 7% in the case of Celanese (see Fig. 18). This fact is established if we are permitted to extrapolate the straight line of Fig. 18 the short distance to the 100% R. H. axis. The sketch area in saturated air is 279 mm^2 and in water is 300 mm^2. The difference between the swelling maxima exhibited by Celanese in water, and in air saturated with water vapor, is an example of von Schröder's paradox.[5] Von Schröder found that if gelatin is immersed in water it imbibes a definite maximum mass of water. If it is then lifted out, and held in the presumably saturated air above the water, it immediately begins to lose a certain amount of water which is very loosely held, and finally attains a new equilibrium water content lower than that attained when immersed. Von Schröder ascribed the difference to lack of saturation for all points above the water, except those in the immediate neighborhood of the surface. Wolff and Büchner[6] claim that the difference becomes smaller if the containing vessel is made smaller. They used a metal vessel immersed in an accurately controlled thermostat bath and having the smallest volume possible. The vessel was silvered on its inner surfaces and had a volume of about 330 c.c. By this arrangement thermal equilibrium would readily be established. The ideal condition would be attained if the specimen could be held for a time and weighed in an air bubble immersed in water at a constant temperature. In Wolff and Büchner's experiments the specimen was removed from the vessel for weighing. This procedure introduces very serious errors. Their conclusions were that the von Schröder effect does not exist except as a function of technique. Katz[7] says the question is not yet settled. The present re-

sults seem to show that the effect is real. The vessel used here fulfills Wolff and Büchner's requirement, in that it is made of metal and is very small in volume (2 c.c.). Convection currents and diffusion are, however, not depended upon for the attainment of equilibrium of vapor pressure. At all times a positive flow of properly humidified air was directed onto the specimen. Condensation upon the interior wall of the vessel can not reduce the vapor pressure on the specimen through removal of water from the vapor phase, because a copious supply of properly humidified air is available for counteracting this effect. The present method is not subject to the difficulties encountered when the specimen has to be removed from the treating chamber for weighing.

The slow rise to maximum swelling exhibited by curve 14, and the rapid fall of curve 15, may shed some light on the phenomena of sorption hysteresis exhibited by gels. The amount of water contained in a gel at a given R. H. depends upon the direction in which the R. H. had been changing. McGavack and Patrick [8] in a study of the adsorption of SO_2 by silica gel, and Sheppard and Newsome [9] working with the sorption of water vapor by cellulose materials, find that the hysteresis loop is such that with falling R. H. the sorbed content is higher than with rising R. H. This means that the adsorbed phase experiences difficulty in getting into or out of the gel. As is usual in work of this kind, swelling was inferred from measurements of gain in mass of the gel rather than from direct measurements of dimensional changes. Only by special procedure in the present experiments could a hysteresis loop be obtained. Combining curves 17 and 18 a loop would be inclosed if, at the end of the run for Fig. 17, a long time elapsed while the area approached the maximum under the influence of saturated air flow.

Pierce [10] explains hysteresis on the basis of the blocking of the surface's crevices by adsorbed water molecules so that the sorbed quantity with rising R. H. is lower than it should be if the total surface of all the crevices were exposed. With falling R. H. the reverse condition would exist. For the existence of a permanent blocking layer the water molecules would be permitted to execute only slight vibrations about a mean position of equilibrium. This is characteristic not of the liquid but of the solid state, except where the molecule is held firmly by the forces involved in adsorption. For blocking by adsorbed water molecules the crevices could not be greater than three molecules wide. The considerable heat motion of water at room temperature presupposes continual evaporation and condensation on the surfaces of the crevices. Blocking of crevices greater than three water molecules wide could not be permanent and could have no serious effect on the free interchange of vapor from cell to cell, or between the surrounding atmosphere and the cells of the gel. From the point of view of a water molecule the surface of a cellulose micelle does not possess the smoothness and surface imperviousness tacitly assumed in Pierce's mechanical blocking process. There is no reason to expect that the truly adsorbed layer would be the cause of hysteresis, for it is held with equally great strength whether the R. H. is rising or falling.

A blocking action, due to the closing of the outer or surface crevices when swelling first starts with increasing R. H., is excluded, for it could occur only through the swelling of the individual micelles, and this pre-

supposes penetration of water into the micelles between the principal valence chains. This is inconsistent with the fact that the fibres discussed here do not exhibit unlimited swelling.

A more plausible explanation of sorption hysteresis is that offered by McGavack and Patrick.[8] They showed that hysteresis in SO_2 silica gel adsorption could be eliminated if the gel were prepared free of air. They intentionally admitted a small amount of air to a previously air-free gel and then observed the appearance of hysteresis. A very small amount of air has a large effect on the rate of adsorption. With air present it took hours for equilibrium to be established, while in an air-free condition only a few minutes were required. Sheppard and Newsome[9] also found that sorption hysteresis could be diminished in the case of cellulose materials by reducing the air pressure. They could not eliminate the hysteresis entirely by pumping to 0.005 mm. pressure, and therefore concluded that the cause of hysteresis is not adsorbed air. It is extremely difficult to remove the last traces of adsorbed air by vigorous pumping without the use of high temperatures which would completely destroy cellulosic materials. Sheppard and Newsome's conclusion on this account seems invalid. McGavack and Patrick were able to get around the difficulty by preparing their adsorbent (silica gel) in an air-free condition.

In the experiments described the specimen was exposed to a mixture of air and water vapor. We have therefore to deal, not with adsorption and swelling phenomena in a single homogeneous vapor, but with the more complicated system involving both air and water vapor. On the assumption that air as well as water vapor may enter into the specimen, and may be adsorbed on the micellar surfaces, the following qualitative explanation of the results obtained is offered: The initial rise of the curve in Fig. 17 is due to the easy replacement by water vapor of air loosely held in the capillary spaces between micelles. The slow final attainment of maximum area is due to the difficulty in replacing the last traces of air firmly adsorbed on the micellar surfaces. Conversely, the rapid initial fall of curve 15 is due to the ease with which the water, loosely held in the capillaries, is removed.

The reason for the peculiar shape of curve 15 after the first drop is obscure. An explanation will be ventured here for what it may be worth in the light of future studies: After complete removal of "capillary water" the firmly held adsorbed layer of water molecules remains, and conceivably serves as a cementing agent holding the "brush heap" micellar structure[11] of the gel (Celanese) more compactly together, and thus accounts for the minimum area of 250 mm^2. With further drying the adsorbed water film is gradually replaced by adsorbed air. At a certain time the adsorbed layer consists of a mixture of water vapor and air. The mixture apparently has a smaller adhesive power than either pure water or pure air, allowing the "brush heap" to spring out to a larger volume corresponding with the small maximum near 2.5 hours. The final fall again to about 250 mm^2 may be due to the complete replacement of water by air. The idea of a cementing action expressed here is not inconsistent with the fact that strength of single acetate rayon fibres increases steadily with increasing dehydration (v. Celanese curves in [2]). The action implied is that exhibited by a liquid film between two plates accurately in contact at

many surface points. The plates adhere like a pair of Johansson gauge blocks. The liquid film facilitates slipping between the blocks parallel to the wetted interface. The low strength of a wet fibre is due principally to the saturation of the van der Waal's forces of the hydroxyl groups on the surfaces of the micelles by the adsorbed water molecules, whereas in the dry state the secondary valencies (van der Waal's forces) are satisfied by the OH groups on neighboring micelles thus contributing to the micellar adhesion.

In the two equilibrium curves given in Figs. 17 and 18 for rising and falling R. H., note that with rising R. H. the slope is smaller. In the light of the adsorption and desorption time-studies (Figs. 14 and 15) it is evident that 18 is the true equilibrium curve; for with R. H. falling from 100% the rapid rate of change of area insures the attainment of equilibrium in the time interval between points. With rising R. H. expansion of area is so slow that Fig. 17 is not a true equilibrium curve. All points are too low.

The Celanese fibre studied here possessed a low degree of micellar orientation. There are many intermicellar crevices. In a well oriented fibre the micelles are closely packed and a swelling medium penetrates slowly. It is to be expected, therefore, that the rate of swelling of fibres of given chemical composition would be a function of micelle orientation. Swelling phenomena may be more simple with a dispersing medium whose molecules do not associate in complex aggregates as they do in water.

The usual method in the study of swelling processes is to determine the so-called adsorption isotherm which was first enunciated by Freundlich [12] for the simpler case of adsorption of gas on a solid. For colloidal adsorption it is usual to express the mass of vapor adsorbed per gram of dry adsorbent as a function of the vapor pressure of the system. Dimensional changes accompanying swelling are usually only inferred. In the present case they were measured directly.

The study of swelling was initially undertaken to establish a correction for area-change when testing the fibres in varying R. H. The results obtained have been discussed at some length because the writer believes that the results and the experimental method have some novelty in their bearing on swelling phenomena. In a later report a thermodynamic discussion will be given, wherein the similarity of the three processes (1) swelling, (2) dilution of solutions, and (3) osmosis, will be pointed out. The relation of swelling to adsorption phenomena and the molecular forces in the interfacial layers between phases will also be discussed.

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Fabric Wear Resistance and Methods of Measuring It

Summary of Discussion at U. S. Institute Conference; Those Present; Action Upon Results

"The Wear of Fabrics and the Development of Methods for Measuring Resistance to Wear" was the first subject selected by U. S. Institute for study. Since then a large amount of uncoordinated work has been in progress throughout the country upon various phases of the subject, including a fellowship of the Textile Foundation on "Strength and Wearing Properties of Textile Fabrics."

To get an up-to-date and clear picture of what has been done, of what is being done, and of what needs to be done U. S. Institute's Research Council held a conference on the subject in the Hotel Commodore, New York City, March 24, that brought together what was probably the largest textile group that ever discussed a single research subject. A summary of the discussion, and of the actions voted by the Research Council immediately after the meeting, follows.

CHAIRMAN Emley pointed out the need for distinguishing between the destruction of fabrics by wear and the destruction by time alone, and suggested that the discussion be confined to the former. He also indicated the lack of relationship between cost and value.

Mr. Freedman, in a key-note address, listed the various manufacturing and finishing factors which affect the durability of fabrics, and the various factors which must be controlled in any testing method. In particular, there is the difficulty of knowing when the test has been completed. He presented many test results and emphasized the general lack of uniformity in the wear resistance of fabrics nominally of the same kind.

Mr. Simon asserted that the customer is always right; that no test method is satisfactory unless the type of wear produced by it is the same as that produced by the customer. To develop a test method, the first step is the examination of worn fabrics to ascertain the nature of the wear. Then a test machine can be designed to produce the same kind of wear. He demonstrated a machine (built by Alfred Suter) for testing hosiery, and referred to others for testing linings, overcoatings and upholstery. Linings are treated with artificial perspiration during the test. The test for overcoatings has been checked against service by co-operation with Hart, Schaffner and Marx. Price has practically no relation to durability. Based upon wear of heels and toes in actual use a 50-cent stocking may outwear one costing $1.50 a pair.

Mr. Sommaripa and Miss O'Brien emphasized the necessity of checking the results obtained with any testing machine against actual service. Mr. Masland suggested the use of statistical methods for analyzing service tests.

Mr. Quig emphasized the importance of conducting the tests in an atmosphere of controlled humidity, which was concurred in by Dr. Hardy. Mr. Scott pointed out that this is not sufficient; that the test causes a rise of temperature which will affect the moisture content of the fabric. Mr. Hunter stated that the finish of the fabric will also affect its moisture content, and Mr. Von Bergen stated that the weave and the pH must also be considered. Mr. Ashcroft recommended that all tests be made at the same temperature and humidity regardless of the moisture content.

Mr. Masland suggested that the rate of rise of temperature of the specimen being abraded might serve as a criterion for resistance to wear. He also suggested that the Bierer-Davis bomb, used as an accelerated ageing test for rubber, might prove of value in examining wool.

Mr. Russman recommended against the use of emery cloth as an abradant. Mr. Scott stated that standard grades of cloth can be obtained. Mr. Davieau and Mr. Ditton stated that they have used carborundum satisfactorily. Mr. Davieau is now using a 16 mesh bronze wire. Mr. Hopkins suggested that a different type of abradant may be necessary for each kind of fabric.

Mr. Simon, Mr. Russman, Prof. Schwarz and Dr. Emley emphasized the importance of the time element in abrasive testing and seemed to agree that a too greatly accelerated test may introduce factors that render impossible, or difficult, correlation with wear in actual service.

Prof. Schwarz divided the problem into three parts: (1) Duplication of service conditions. (2) Duplication of results of service conditions. (3) Ascertainment of what laboratory conditions will duplicate the results of service conditions.

Prof. Ball also suggested three divisions: (1) Study of the forces involved in abrasion. (2) Study of the properties of fibres and fabrics. (3) Empirical study of machines.

Mr. Sommaripa suggested that the A. S. T. M. might conduct the study on fibres, the U. S. Institute on fabrics.

Dr. Smith and Mr. Jelleme recommended that fabrics be classified in accordance with the types of service.

Dr. Smith and Mr. Sommaripa suggested consideration of types of wear other than abrasion. Mr. Masland recommended consideration of the various kinds of stresses to which fabrics are subjected. Flexure, fatigue, tearing, slipping, catching, gouging, stretching, compression, were suggested by various members.

Mr. Hopkins drew attention to the fact that the consumer in buying carpets or rugs gives first consideration to color and design, then to comparative wearing quality of those that are equally satisfactory otherwise. Dr. Saxl held that in wear tests of dress fabrics it will be well to bear in mind that such fabrics, or garments made therefrom, are more often discarded because of change in fashion than because of wear. Prof. Schwarz emphasized the desirability of analyzing the subject of how much wear is objectionable.

Mr. Freedman moved that work be confined to resistance to abrasion. Carried unanimously.

Miss O'Brien and Mrs. McGowan reported that much work is being done in schools of home economics, studying the resistance of fabrics to abrasion, mostly on sheetings, shirtings and table damasks. Mr. Quig expressed surprise that the work of these schools had not been recognized by the grant of a Textile Foundation fellowship.

Mr. Ashcroft reported that the six rug and carpet manufacturers present all used the Bureau of Standards wear-testing machine, and that any investigation which might affect their industry should be confined to a study of this machine.

Questionnaire

During the meeting, a questionnaire was taken, with the following results: (1) What kind of fabrics do you make wear tests of? Answers: Carpets, 6; rayon underwear, 3; hosiery, 5; linings, 6; dress goods, 17; sheeting, 1; shoe linings, 1; miscellaneous mechanical fabrics, 3; miscellaneous knit fabrics (exclusive of hosiery), 1; pile fabrics (exclusive of carpets), 6; household fabrics, 1.

(2) What machine or machines do you use? Answers: M. I. T. design, 2; Wyzenbeek, 7; Bureau of Standards Carpet, 6; U. S. Testing Co., 1; Schopper, 1; Industrial By-Products & Research Corp. hosiery type, 1; Industrial By-Products & Research Corp. lining type, 1; Macy, 1; miscellaneous, 3.

(3) What is the purpose of your wear testing? Answers: (a) Mill control, 12; (b) Research, 17; (c) Acceptance, 15.

Present at the Conference

A. G. Ashcroft, Alex. Smith & Sons Carpet Co., Yonkers, N. Y.; Prof. H. J. Ball, Lowell (Mass.) Textile Institute; K. Barnard, J. E. Bradley, W. O. Jelleme, Pacific Mills, New York City; Messrs. Bauman, McCollom and O'Shaughnessy, National Dyeing & Printing Co., Paterson, N. J.; W. Beckwith, Chas. P. Cochrane Co., Philadelphia, Pa.; Harry Benson, Cheney Bros., South Manchester, Conn.; Mr. Benzing, American Bemberg Co., New York City; J. Robert Bonnar, American Printing Co., Fall River, Mass.; W. C. Campbell, Hardwick & Magee, Philadelphia, Pa.; W. W. Chase and E. D. Fowle, Textile World, New York City; C. H. Clark, Sec., U. S. Institute for Textile Research, Boston, Mass.; James W. Cox, Jr., Cox & Fuller, New York City; A. E. Davieau and C. J. Huber, U. S. Testing Co., Hoboken, N. J.; R. DeBow and A. Peterson, Marshall Field & Co., New York City; E. W. Ditton and L. S. Zisman, Gotham Silk Hosiery Co., New York City; Alban Eavenson, Eavenson & Levering Co., Camden, N. J.; J. O. Ellis and K. E. Rice, Sidney Blumenthal Co., Shelton, Conn.; Dr. W. E. Emley, U. S. Bureau of Standards, Washington, D. C.; Ephraim Freedman, R. H. Macy & Co., New York City; E. Friderici and W. Stuart Wingard, Mohawk Carpet Mills, Amsterdam, N. Y.; R. L. Hall and D. M. Stewart, American Woolen Co., New York City; Dr. J. I. Hardy, Bureau of Animal Industry, Washington, D. C.; B. L. Hathorne, New York City; G. S. Hiers and W. R. Keen, Collins & Aikman Corp., Philadelphia, Pa.; G. E. Hopkins, Bigelow-Sanford Carpet Co., Thompsonville, Conn.; C. Huber and E. Messmer, Textile Dyeing & Printing Co., Fairlawn, N. J.; H. J. Jaquith, Minot, Hooper & Co., New York City; H. Levine, Textile Testing & Re-

search Laboratory, New York City; Mr. Marks, Rayon Editor, Daily News Record, New York City; C. H. Masland, 2nd, C. H. Masland & Sons, Carlisle, Pa.; J. J. McGibbon, American Glanzstoff Corp., New York City; Ellen B. McGowan and Helen Rimmonds, Teachers College, Columbia Univ., New York City; H. A. Mereness, Silk Association of America, New York City; Raymond E. Miskelly, Plymouth Cordage Co., Plymouth, Mass.; Ruth O'Brien, U. S. Bureau of Home Economics, Washington, D. C.; E. T. Pickard, Sec., The Textile Foundation, Washington, D. C.; L. Paris and T. A. Printon, National Oil Products Co., Harrison, N. J.; J. B. Quig, Alex. Sommaripa, L. B. Dennett, G. J. Groh and A. S. Hunter, Du Pont Rayon Co., New York City; Arthur Russman, Howard Clothes, Brooklyn, N. Y.; Robert E. Sargent, Tubize Chatillon Corp., New York City; Dr. Irving J. Saxl, Waypoyset Mfg. Co., Central Falls, R. I.; Prof. E. R. Schwarz, Massachusetts Institute of Technology, Cambridge, Mass.; David C. Scott, Henry L. Scott & Co., Providence, R. I.; Chas. L. Simon, Industrial By-Products & Research Corp., Philadelphia, Pa.; H. DeWitt Smith, A. M. Tenney Associates, New York City; Frank Stutz, Better Fabrics Testing Bureau, New York City; Alfred Suter, New York City; D. Veit, Colonial Mills, Inc., Hemp, N. C.; Werner Von Bergen, Forstmann Woolen Co., Passaic, N. J.; P. J. Wood, Apex-Oriental Corp., Haledon, N. J.

Actions Adopted by the Research Council

At a meeting of the Research Council of U. S. Institute for Textile Research, Inc., immediately following adjournment of the fabric wear conference March 24, the following actions were voted, subject to acceptance by U. S. Institute's Executive Committee.

(1) That the initial study of fabric wear be confined to resistance of textile fabrics to abrasive wear. (Abrasion may consist of rubbing action plus or minus flexing.)

(2) That, supplementing this study, or as an integral part of it, the Research Council shall undertake to collect, from all who are known to have been engaged in the correlation of machine testing of abrasive wear with fabric wear in service, samples of textile products and garments illustrating such wear, together with a summary from each person thus engaged of how each class of fabrics and garments wear out. These samples and the summaries are to be forwarded to the U. S. Bureau of Standards, Washington, D. C., c/o Dr. W. E. Emley, chief, Organic & Fibrous Materials Division, for analysis. The Department of Textile Technology, Mass. Institute of Technology, has offered to co-operate in this work.

(3) That, if possible, arrangements be made for the study under the Associate Plan at the Bureau of Standards under the direction of Herbert F. Schiefer, who has conducted similar studies at the Bureau of Standards, and that if this arrangement be consummated, Mr. Schiefer be designated to contact other similar work in progress throughout the country.

Present at the meeting of the Research Council were the following: W. E. Emley, Chairman; H. DeWitt Smith, Vice-Chairman; C. H. Clark, Alban Eavenson, Prof. E. R. Schwarz.

Flax Growing and Manufacture to be Studied

A NEWS release of the Textile Foundation, under date of March 24, states that "during recent months there has been a revival of interest in the subject of flax production, preparation and utilization in the United States. Because of this interest in flax, the Textile Foundation called a meeting in Washington, D. C., of leading chemists, paper and textile manufacturers, flax growers, technicians, government officials and others, who had had experience in different phases of flax with a view to obtaining their cooperation and advice.

"As a result of the facts brought out at this meeting the Foundation has decided to launch a series of investigations and experiments ranging through the field of production, machine and chemical preparation, utilization in the manufacture of paper, and the production of linen fabrics on cotton mill machinery. If the production of flax in the United States proves successful, the farmer will have an added crop. The American-grown flax will not interfere with cotton, but may supplant some of the raw flax imported into the United States for manufacture into certain products.

"H. H. Willis, in addition to his duties as dean of the Textile School of Clemson College (S. C.), will devote part of his time to correlating the different activities and seeing that they move forward with reasonable speed. A limited amount of pedigreed flax seed has been obtained and arrangements made for its planting in different localities of the following states: Virginia, West Virginia, North Carolina, South Carolina, and Tennessee. Flax production by private enterprise in Georgia and South Carolina will be included in this study."

An Old Domestic Industry

Flax was grown for fibre in practically every community in the New England and Middle Atlantic States during Colonial times, and was spun and woven by hand as a common household industry. Because of the laborious and noisome methods of retting, breaking and hackling required to decorticate and degum the fibre the use of flax declined rapidly as soon as the supply of cotton became adequate and cheap. Although there has always been a small flax spinning and weaving industry in this country (some 18 mills at present) these manufacturers have imported their raw material, and have shown little interest in efforts to raise fibre flax here in competition with countries whose labor costs are very low. In Canada, however, there have been continued efforts to increase fibre flax growing, yet despite government aid and the introduction of modern methods it is a declining industry. The only fibre flax cultivation in this country in recent years has been in the states of Oregon and Washington, and on a small scale principally for local utilization.

Every few years some inventor brings forward new and patented methods for chemical degumming and mechanical decorticating, and usu-

ally, instead of endeavoring to secure their acceptance in foreign countries where the growth, preparation and manufacture of flax is an established industry, they almost invariably confine their efforts to this country and their record thus far has been a considerable number of notorious failures, of which the old New England Flax Fibre Co. is an outstanding example. Most of these inventors, however, have confined their efforts to attempts to utilize the millions of tons of flax straw that are burnt annually in the northwestern states, and that are the refuse of flax grown for seed, lacking nearly all of the properties of fibre flax. If the flax study to be undertaken by the Textile Foundation, or some of its other studies now in progress, could be directed to the scientific definition of the basic differences between flax fibre grown for fibre and that of flax grown for seed it might prevent much misdirected inventive effort.

There has been a revival recently in this country and abroad of inventive efforts to utilize tow (the waste of line flax) and cut line flax for spinning on cotton machinery. They involve also chemical methods of retting and improved machine methods of fibre preparation.

Textile Foundation's Report on Textile Education

RESULTS of a six months' study of educational facilities and methods of training men for the textile industry have just been published by the Textile Foundation. This practical report, now available from the Foundation, surveys the courses offered by eleven textile engineering schools or institutes with a view to the requirements of a nine billion dollar industry for trained personnel.

The survey was conducted by Frederick M. Feiker, a graduate of Worcester Polytechnic Institute and now executive secretary of the American Engineering Council of Washington. His advisory committee consisted of Dr. Karl T. Compton, president of Massachusetts Institute of Technology; Dr. E. C. Brooks, vice-president of the University of North Carolina, and R. E. Doherty, dean of the School of Engineering, Yale University.

Opportunities for trained men in the textile industry are reviewed in the report, as well as the opportunity for textile schools to meet the new requirements for trained personnel. The hearty co-operation of the various textile schools and of numerous executives of the textile industry has aided greatly in the preparation of this report for the Textile Foundation. Edward T. Pickard, secretary of the Textile Foundation, Commerce Bldg., Washington, D. C., will welcome any inquiry concerning conditions under which the present study of textile education is available.

Abstracts

This section is compiled under the direction of the Committee on Abstracts and Bibliography: Prof. E. R. Schwarz, Chairman, Dr. W. E. Emley, Prof. Louis A. Olney and M. W. Weiss.

I. Fibres (Synthetic and Natural) and Fibre Analysis

Action of Alkaline Copper-Solution on Silk Fibroin. V. Application of the Conductometric Titration to the System of Fibroin-Copper-Amine (1 and 2). VI. Mechanism of the Solution of Fibroin in Copper-Amine Solution. Y. Takamatsu. *J. Soc. Chem. Ind. Japan* 36, Suppl. binding, 1933, P. 662–8, 668–72; cf. *Chem. Abs.*, 1934, V. 28, P. 901, 1539. (W)

Cotton: Effect of Atmospheric Humidity on Moisture Content of. Nazir Ahmad. *Tex. Mfr.*, December, 1933, P. 484–485.

The technical and commercial importance of moisture content of cotton is recognised; the relation of moisture content of cotton in the bale to atmospheric humidity has been carefully investigated in experiments referred to. (S)

Delustering of Rayon. G. Choisy. *Russa*, 1933, V. 8, P. 673–7.

A description of H. Dreyfus' process for reducing the luster of rayon by fixation of TiO_2 or other white or practically white, insol. Ti compds. (Copied complete from *Chem. Abs.*, 1934, V. 28, P. 332.) (W)

Formaldehyde in the Treatment of Textile Materials. A. J. Hall. *Am. Dye. Rptr.*, June 19, 1933, P. 380–381, 399–401.

In this article attention is drawn to the possibilities of chemically combining cellulose fibres (cotton and viscose rayon) with formaldehyde, and an account of researches along these lines is reviewed. (S)

Silk Fibres in Reeling: What Substance is Responsible for the Cohesion of. G. Colombo. *Boll. uff. R. Staz. sperim. Seta.*, 1932, V. 2, P. 27–28 (through *Chem. Zentr.*, 1933, I, 2018).

Cocoons not heated and cocoons heated at 100° or 140° give up about the same amount of soluble material to water at 65°. The cohesion of the fibres in raw silk is therefore ascribed to the γ-fraction of sericin, which is insoluble in water at 65°, but soluble in boiling water. (Copied complete from *J. T. I.*, May, 1933, P. A238.) (S)

SWELLING OF PROTEIN FIBRES. II. SILK GUT. D. Jordon Lloyd and R. H. Marriott. *Trans. Faraday Soc.*, 1933, V. 29, P. 1228–40; cf. *Chem. Abs.*, 1933, V. 27, P. 2864.

Silk fibres (fibroin) were subjected to the action of water, to NaOH 0.5–10 *N*; to HCl 0.5–10 *N*, to 2 *M* solns. of the salts: NaCl, $NaNO_3$, LiI; and to satd. solns. of urea and thiourea. The fibres absorb H_2O to about 30% of their wt. The absorption increases with the addn. of NaOH up to 6 *N* and decreases slightly for higher concns. The swelling is accompanied by splitting into fibres, and a permanent ability to swell in *pure water* more than before alkali treatment. The water is imbibed and the alkali aids by irreversibly breaking the coördinate linkages between the imino group of one chain and the carbonyl group of a parallel chain. The swelling is not increased much by acids less than 2 *N* but the strength of the fibres is destroyed. At 10 *N* concn., HCl dissolves the silk in 24 hours. Salt, urea and thiourea cause slight swelling and weakening of fibres. The strong birefringence of silk fibres falls off slowly in acid and rapidly in alkalies. None of the treatments affected the X-ray diagrams. (Copied complete from *Chem. Abs.*, 1934, V. 28, P. 901.) (W)

VISCOSITY INVESTIGATION OF SILK SOLUTION. I. EFFECT OF NICKEL AND COPPER IN THE AMMONIACAL SOLUTION. H. Sobue and S. Manago. *J. Soc. Chem. Ind., Japan* 36, Suppl. binding, 1933, P. 576–9; *Chem. Abs.*, 1934, V. 28, P. 332. (W)

WEAKLY ACETYLATED FIBRE CELLULOSES. A. Rheiner. *Angew. Chem.*, 1933, V. 46, P. 675–81.

The prepn. and properties of weakly acetylated fibre celluloses, their dyeing properties together with those of other fibre cellulose esters and their applications are discussed. Photomicrographs of dyed sections and acetylation curves are presented. Twenty-two references. (Copied complete from *Chem. Abs.*, 1934, V. 28, P. 316.) (W)

X-RAY INVESTIGATION OF NATURAL AND REGENERATED SILK. I. Sakurada and K. Futino. *Sci. Papers Inst. Phys. Chem. Rsch.* (Tokyo), 1933, V. 21, P. 266–9.

Identical X-ray photograms are obtained from Antheraea pernyi and Antheraea yamamai while the photogram from Bombyx mori is different. One prepn. of tegusu gave a photogram identical with that from Bombyx mori while two other prepns. of tegusu gave photograms similar to those of the pernyi and the yamamai. Dispersion and regeneration changes the lattice structure of the silk fibrils very slightly. (Copied complete from *Chem. Abs.*, 1934, V. 28, P. 331.) (W)

III. CHEMICAL AND OTHER PROCESSING (NOT OTHERWISE CLASSIFIED)

DIRECT DYES AND CELLULOSE: MODERN IDEAS CONCERNING THE. S. M. Neale and L. H. Griffiths. *Am. Dye. Rptr.*, November 6, 1933, P. 651–654.

A brief introductory discussion of several hypotheses relative to the kinetics of the dye process. In the absence of adequate data the picture is necessarily incomplete. (S)

DYE MIXTURES: ANALYSIS OF. Walter E. Mathewson. *Am. Dye. Rptr.*, December 4, 1933, P. 721–726, 745–746.

Data and procedure are given for the systematic analysis of dye mixtures containing any of the commoner water soluble dyes. (S)

DYEING ACETATE RAYON: RECENT IDEAS IN. H. Yorke. *Dyer*, 1933, V. 70, P. 235, 237, 247.

Sapon. of acetate rayon by treatment first with a relatively strong soln. of NaOH followed by treatment with a more dil. soln. is claimed to give more uniform results and to carry less risk of tendering. Acetate pile fabric may be dyed with direct cotton colors, if it is first padded with a soln. of viscose in 8 to 12% NaOH soln. Methods for mordanting acetate rayon with metallic salts usually include a prior treatment of the yarn with a swelling agent. This can be avoided by incorporating the mordant in the yarn during the spinning operation. The dye can also be incorporated in the spinning soln. The dyes manufactured especially for acetate rayon and their application are described. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 5544.) (W)

DYEING COTTON GOODS: FRICTION MARKS IN. Charles E. Mullin. *Tex. Col.*, 1933, V. 55, P. 369–70.

Friction marks in cotton piece goods are mechanically damaged fibres, caused by too much tension in drawing the pieces in the finishing plant, by too little water in the rope washer or by insufficient material in or the improper loading of the kier. Usually the damaged fibres dye a deeper color than the normal fibres. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 5545.) (W)

EMULSIFYING OILS: SIMPLE METHOD FOR. C. F. Goldthwait. *Am. Dye. Rptr.*, Oct. 9, 1933, P. 589–590, 622.

It is stated that one of the essentials in preparing oil emulsions is to have present in the emulsifier just enough water. A number of suggestions or 'kinks' are noted to aid the worker. (S)

KNITTED WOOL GOODS: UNSHRINKABLE FINISH OF. S. R. Trotman. *Tex. Mfr.*, December, 1933, P. 489–491.

The effects of the presence of acid or salts in chlorinating liquor; effects of temperature; and the action of bromine. (S)

PRINTING: CONVERTER'S GUIDE TO. Benj. D. Blackman. *Silk Digest Wkly.*, 1933, V. 24, No. 16, P. 9–11; No. 21, P. 9–10, 12.

Chemical processes preparatory to printing are described. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 3826.) (W)

PRINTING: FIXATION BY ALBUMIN IN, AND A METHOD OF PERFECTING IT. Ed. Justin-Mueller. *Bull. soc. ind. Rouen*, 1933, V. 61, P. 147–50.

In textile printing, certain org. colors fixed by albumin, which have incomplete resistance to boiling soap solution, can be rendered more resistant by treatment, after steaming, in a bath of CH_2O followed immediately by drying on drums. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 3826.) (W)

PROTECTIVE KHAKI COLORS. N. A. Suikhra. *Anilin. Prom.*, 1932, V. 2, No. 5–6, P. 23–30.

The various forms of fastness of khaki dyeings of sports and military garments are discussed. The results obtained by lab. tests and in practical wear are thus summed up. After-treating with Cu salts increases the fastness to light and washing without impairing the strength of cloth. Skein-dyed fabrics give faster khaki dyeing than piece dyed. The character of interlacing of threads in weaving influences the fastness of dyeing to friction and washing. Khaki dyes from anthracene and hydroxyazobenzene have the highest fastness to light, while khaki dyeings in the skein with indanthrene dyes will last the life of the garment. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 5543.) (W)

RAYON: RECOGNITION AND DETERMINATION OF DYE FAULTS IN, WITH THE AID OF THE CIRCULAR KNITTING MACHINE. Dr. Herbert Max Ulrich. (German.) *Die Kunstseide*, June, 1933, P. 210–14.

The use of the circular knitting-machine for judging the dyeing properties of rayon is described. The development of a standard method for the examination of the dyeing properties of viscose is attempted for the first time. Several reactions for detecting dyeing-faults in rayon are indicated. (S)

RAYONS: CHEMICAL ANALYSIS OF. MICRO-DETERMINATION OF METALS IN COMMERCIAL RAYON YARN. B. P. Ridge, Mary Corner and H. S. Cliff. *J. T. I.*, Aug., 1933, P. T293–T308.

The accurate determination of very small amounts of any one metal in the presence of others and of a large quantity of organic matter presents numerous difficulties, and hence it should be of value to place on record a description of methods that have been found to give reliable results in the case presented by the analysis of rayons. The present paper is devoted exclusively to such experimental procedures; the majority of the values actually found have already been published. (S)

RAYON AND ITS DYE SELECTIVITY. A. E. Sunderland. *Tex. Col.*, 1933, V. 55, P. 458–62, 492.

A large proportion of the variation in dyeing viscose rayon appears to be due to the presence of sol. and insol. salts in the rayon. The rate of coagulation of the viscose due to differences in chem. compn. or variation in the spin bath of faulty equipment may also cause dyeing differences. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 4404.) (W)

"RAYON OILS." PROPERTIES, MARKETS AND USES OF LUBRICANTS AND SOFTENERS ON SYNTHETIC YARNS. Chas. E. Mullin. *Chem. Markets*, 1933, V. 33, P. 129–32; *Chem. Abs.*, 1933, V. 27, P. 4932. (W)

SOME AUXILIARY PRODUCTS USED IN THE TEXTILE INDUSTRY. J. Abramovitch. *Tiba*, 1933, V. 11, P. 325–39.

A review of the properties of detergent, wetting and protective agents. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 3615.) (W)

STAINS AND THEIR REMOVAL. F. C. Pratt. *Tex. Mfr.*, April, 1933, P. 165.

Various methods of removing stains and the new and old solvents. (S)

SULFONATED OILS: DETERMINATION OF ORGANICALLY COMBINED SULFURIC ANHYDRIDE IN. Ralph Hart. *Am. Dye. Rptr.*, November 20, 1933, P. 695–704.

A description of the more important methods together with data on analyses by a number of independent observers is given. There is also included informative comment by members of the A. A. T. C. C. sub-committee on sulphonated oils. The sulfuric acid-titration method and the ash-gravimetric method are recommended. Standard procedure is given. (S)

UNSHRINKABILITY OF WOOL IN INDUSTRIAL PRACTICE: OBTAINING. C. H. Edwards. *Rev. gen. mat. color.*, 1932, V. 36, P. 390–3; 1933, V. 37, P. 351–4; *Chem. Abs.*, 1933, V. 27, P. 4403.

A process is described. A fabric which absorbs 2% Cl should have a bath contg. 3% Cl. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 5984.) (W)

VAT COLORS: REDUCTION PRODUCTS OF. E. Herzog. *Rev. gen. mat. color.*, 1933, V. 37, P. 284–5.

Yellow leuco derivs. are easily extd. from an alk. bath by EtOAc soln. with a double-bulb extn. funnel. Leuco derivs. of other colors are extd. with greater difficulty. Reduction products of benzanthraquinone, treated with acid, develop a carmine-red color, which is due to a colloidal condition, as proved by the Tyndall effect. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 4931.) (W)

WETTING-OUT AGENTS AND MODERN MERCERIZATION METHODS. A. J. Hall. *Am. Dye. Rptr.*, Oct. 23, 1933, P. 623–626, 628.

A record of progress in improving the efficiency of mercerization by better wetting out. Tabulated data and several charts are offered to show the rates of shrinkage with and without wetting-out agents. (S)

WETTING AGENTS IN TEXTILE PROCESSING. Harvey A. Neville and Charles A. Jeanson III. *Am. Dye Rptr.*, Sept. 11, 1933, P. 542–543.

The first of a series of three articles which have important bearing on the mechanism of wetting out and softening. The articles contain information of value from an educational standpoint. Aromatic sulphonates, surface tension measurements, maximum surface activity and surface activity of isomers are dealt with in the present article. (S)

WETTING AGENTS IN TEXTILE PROCESSING. II. ADSORPTION OF WETTING AGENTS BY WOOL. Harvey A. Neville, Charles A. Jeanson III, and Arthur L. Smith. *Am. Dye. Rptr.*, Sept. 25, 1933, P. 565–566.

Part II of a series of three articles. The present discussion notes that although the new types of wetting agents are stable in acid solutions, they are so strongly adsorbed from solutions of high acidity that they can hardly be economically employed under these conditions. A pH range of 6 to 10 is considered good where it can be employed. (S)

WETTING AGENTS IN TEXTILE PROCESSING. Harvey A. Neville and Charles A. Jeanson III. *Am. Dye. Rptr.*, Oct. 9, 1933, P. 618, 621.

The last of three articles, the present discussion noting an apparent anomaly. Gardinol is stated to decrease the adsorption of a basic dye in alkaline solutions. Alternative explanations are offered. (S)

IV. Research Methods and Apparatus

Copper in Textiles: A Comparison of Methods for the Determination of Small Amounts of. Walter M. Scott. *Am. Dye. Rptr.*, Oct. 9, 1933, P. 605–609.

A review of previous work from 1912 is offered and in addition to the methods of test involving colorimetric determination with potassium ferrocyanide, and volumetric determination with sodium thiosulfate, suggestion is made that a colorimetric technique with sodium diethyldithiocarbamate and a volumetric method using the nitroso-chromotropic reagent be employed. Here it is probable that less than 1 gm. sample of fabric could be used. (S)

Fabrics: Measuring the Textile Qualities of. *Tex. Mfr.*, Nov., 1933, P. 435; *Tex. Rsch.*, V. III, No. 8, P. 388, No. 10, P. 505.

Brief descriptions of the Bureau of Standards Flexometer and Compressometer. (S)

Fastness to Light: Conditions of Temperature and Relative Humidity in Testing, by Means of Artificial Illumination. R. O. Hall. *Am. Dye. Rptr.*, July 17, 1933, P. 437–441, 444.

The mean conditions of temperature and relative humidity under which materials are exposed to the carbon arc in certain existing fading equipments have been determined. The temperature at the exposed face of the sample is in general higher and the relative humidity lower than the values for the Standard Sun Test recommended by the American Association of Textile Chemists and Colorists. A new equipment is described which embodies accurate control of both temperature and relative humidity at predetermined values. Note that this article appears also in *Tex. Mfr.*, October, 1933, P. 410. (S)

Fluorescence Microscope and the Determination of Mercerisation of Cotton: Use of the. E. Grunsteidl and F. Hanika. *Tex. Mfr.*, September, 1933, P. 373–374.

Methods and instruments for microscopic ultra-violet tests, with the use and limitations in testing cotton for mercerization. (S)

Hygrometer: A New Pattern. *Nature*, September 23, 1933, P. 485.

Particulars have been received from Messrs. A. Gallenkamp and Co., Ltd., 17–29 Sun Street and 1–3 Clifton Street, Finsbury Square, London, E. C. 2, of a new pattern of hygrometer. A sensitive absorbent fibre is used in place of the usual hair of the hair hygrometer, and it is claimed that by this means the need for frequent adjustment is avoided. A pointer connected with the fibre registers percentage relative humidity on a graduated dial. (S)

Negative Polarisation in Fluorescence. K. S. Krishnan and S. M. Mitra. *Nature*, Feb. 11, 1933, P. 204–205.

A repetition of Wawilow's work with polarised light on dyestuffs which confirms the earlier study. (S)

RESEARCH: VALUE OF. Robert E. Rose. *Am. Dye. Rptr.*, Aug. 14, 1933, P. 265–269.

A most readable and interesting discussion of the value of research in general. (S)

STATISTICAL METHODS IN INDUSTRY: APPLYING. Dr. R. H. Pickard. *Tex. Mfr.*, December, 1933, P. 470–471.

Because of the variability of textiles, statistical methods, including sampling techniques, are necessary to proper understanding of test data. The author outlines certain points of interest both for laboratory and process work. (S)

TESTING IN A SPINNING MILL: SYSTEMATIC. A. W. Bayes. *Tex. Mfr.*, December, 1933, P. 477–478.

Practical suggestions on spinning mill testing equipment, lay-out tests, and the use of the results. (S)

TEXTILE FIBRES: MICROCHEMICAL METHODS AS APPLIED TO SPOTS ON. Irvine W. Grote. *Am. Dye. Rptr.*, July 17, 1933, P. 446–448.

A brief treatment of certain micro-chemical techniques as adapted to textile spot analyses intended to stimulate reference to standard texts. (S)

TEXTILE FIBRES: WHAT THE MICROSCOPE SHOWS OF. Sidney Melton Edelstein. *Am. Dye. Rptr.*, July 31, 1933, P. 253–255, 264.

A simple and brief treatment of certain phases of textile microscopy applicable to mill use. Several inaccuracies are apparent, for example, the use of egg albumen fixative *after* removal of the paraffin from a microtome cut cross-section rather than before, and its application *on* the sections rather than to the slide below them. Again the author states that fast coagulation of viscose rayon filaments produces filaments of round cross-section. Further statements as to wool and silk are either loose or in error. A statement that the wool fibre contains "cellulose" material in its medulla is probably a misprint for "cellular." Other statements are not open to this excuse however. (S)

V. ECONOMICS AND MISCELLANY

DEVELOPMENT OF AIR CONDITIONING IN INDUSTRIAL, RESIDENTIAL AND PUBLIC BUILDINGS; ITS EFFECT ON HUMAN BEINGS; THE FACTORS WHICH ENTER INTO ITS DESIGN. P. L. Davidson. *Am. Inst. Chem. Eng.*, Roanoke Meeting, Dec., 1933, (preprint) 69 pp.

The paper discusses the history of air conditioning, its application to the textile industries and rayon, the tobacco industries, the manuf. of asbestos, ceramics, food products, fruit ripening, the packaging of effervescent salts and the manuf. of rope. Investigations on the effect on health, comfort and efficiency are reviewed. The major share of the paper treats of design problems of air conditioning, the source and nature of the heat load, and typical air-conditioning equipment, with a prediction of the future of air conditioning. An extensive bibliography is included. (Copied complete from *Chem. Abs.*, 1934, V. 28, P. 543.) (W)